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COMPRESSION FATIGUE OF PLAIN AND STEEL FIBER REINFORCED CONCRETE

Saga University o Md. Rafiqul Islam
Saga University Norma Febrillet
Saga University Yukihiro Itoh
Saga University Koji Ishibashi
Saga University Tatsuo Ishikawa

1. INTRODUCTION

Addition of steel fibers in concrete matrix has many important effects. Most remarkable among the improved mechanical characteristics of steel fiber reinforced concrete (SFRC) are its superior fracture resistance and resistance to impact and dynamic loads. In this investigation, plain and steel fiber reinforced concrete of similar compressive strength and workability were tested for compression fatigue. The S-N curve and the strain behavior with respect to number of cycles are presented.

2. MATERIALS AND METHODS

Ordinary Portland cement, crushed sand and the coarse aggregate of crushed stone with a maximum size of 25 mm were used .The fine aggregate had a water absorption of 2.14% and a saturated surface dry specific gravity of 2.56. The corresponding values of the coarse aggregate were 1.89% and 2.63 respectively. The fineness modulus of fine aggregate was 2.56. Air entraining agent and water reducing agents were used. The steel fibers were cut wire type and of dimensions 0.5×0.5×30 mm.

The mix proportions and properties of plain concrete and SFRC are shown in Table 1. The fiber contents of SFRC were 0.5% and 1.0% by volume of concrete. Mix proportions were decided to get compressive strength of about 30 MPa with slump of 8±1 cm and air content of 4±1 %. For compressive strength and fatigue test, 20 cm height and 10 cm dia. cylinders were made. Cylinders for plain concrete were made by using internal vibrator

Table 1-Mix Proportions and Proporties of Plain Concrete and SFRC

Mix	Steel Fiber Vol.	W/C	s/a	Quantities kg/m³				Air Entraining Agent	Water Reducing Agent	Slump	Air Content	28 days Compressive Strength (f_c)
				W	C	S	G					
	%	%	%					% of C	% of C	cm	%	MPa
Plain	0.0	62	47.0	167	269	863	997	0.01	0.5	7	5.2	27.9
F0.5	0.5	67	50.2	191	285	865	883	0.006	0.5	9	4.8	29.8
F1.0	1.0	68	52.6	202	297	881	815	0.0075	0.45	9	5.2	27.9

and table vibrator was used for SFRC. Cylinders were kept under water of 20° C for 28 days. Fatigue tests were started after 91 days. Cyclic loading of sine variation with a frequency of 5 Hz was applied by a servo controlled fatigue testing machine. The maximum stress levels were varied from 90% of the 91 day compressive strength to lower values while the minimum stress were kept to 10%. Loading were continued up to 1 million cycles. For each type of mix, three cylinders were tested for each maximum stress level. Additional one or two cylinders were also tested when the scattering were very large. Two wire strain gauges were attached vertically at mid height on the surface of the cylinder in opposite side. Strain readings at regular intervals were recorded by computer from the two strain gauges during the cyclic loading. The average of these two gauges were considered as the strain of the cylinder.

3. RESULTS AND DISCUSSION

The S-N curves are shown in Fig.1. The typical strain versus number of cycles curves are shown in Fig.2, Fig.3 and Fig.4. Plain concrete and both SFRC did not fail in 1 million cycles of maximum stress 70%. SFRC containing 1.0% steel fiber also did not fail in 1 million cycles of maximum stress 75%. It is seen from the S-N curve that the fatigue strength of SFRC is greater than that of plain concrete by many folds. The test results for maximum stress 90% are ambiguous as the plain concrete survives somewhat higher cycles with respect to SFRC. Scatter of test results may also have affected the calculation of average life. Greater number of cylinders must be tested to get reasonable results specially in this stress level. From the obtained strain data, it is seen that the failure strain will be higher for lower maximum stress for both plain concrete and SFRC. SFRC sustain higher strains before fatigue failure than plain concrete. The strain under cyclic loading is somewhat similar to the creep strain of

Steel fiber reinforced concrete, Fatigue, S-N curve, Compressive strength, Strain.
1-Honjo,Saga 840. Phone: (0952)28-8691. Fax: (0952)28-8699

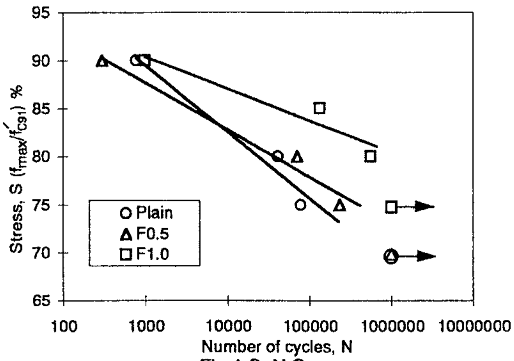

Fig.1 S-N Curve

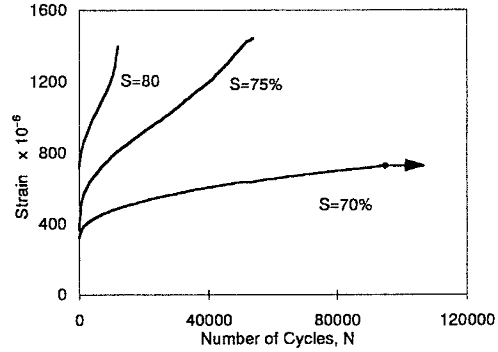

Fig.2 Strain vs No. of cycles-Plain concrete

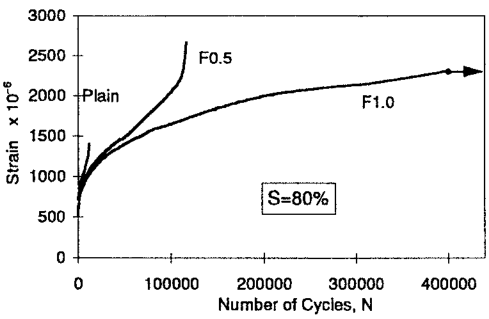

Fig.3 Strain vs No. of Cycles, S=80%

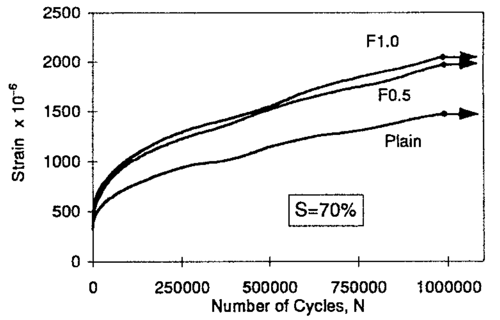

Fig.4 Strain vs No. of Cycles, S=70%

→ indicates that the cylinder did not fail at that number of cycles

concrete under sustained loading. In the primary portion, strain increases rapidly under cyclic loading. In the secondary portion which consists of most of its life span, strain increases gradually with number of cycles. In the tertiary portion prior to failure, again the strain increases rapidly with number of cycles. The average strain rates (SR) in the secondary part of the strain versus number of cycles curves are shown in Table 2. The strain rates for plain concrete and SFRC are almost same in lower stress level. As the stress level increases, the stress rates for SFRC become lower than that of plain concrete; which means, SFRC shows greater resistance to deformation per cycle. The data for 90% stress are again inconsistent as are for S-N curve. Fig.4 shows that plain concrete strains are lower than SFRC at 70% stress level. This was may be due to the difference of mix proportions among the mixes. If the initial strains are considered to be same, then the curves will be almost similar with similar strain rate in the secondary portion .

Table 2-Average strain rate (SR) in the secondary part of strain change

Stress	SR (10^{-3} μ strain per cycle)		
%	Plain	F0.5	F1.0
90	558	3022	1302
80	33.5	11.7	8.2
75	9.9	5.4	1.3
70	0.7	1.0	0.9

4. CONCLUSIONS

For compression fatigue of plain concrete and SFRC containing up to 1% steel fiber with similar compressive strength and workability the following conclusions can be made-

a) Compression fatigue strength of SFRC is higher than that of plain concrete by many folds and the fatigue strength increases with the increase of steel fiber volume content.
b) The failure strain will be higher for lower maximum stress for both plain concrete and SFRC. SFRC can sustain higher strains than plain concrete in each maximum stress level before failure.
c) The strain under cyclic loading is somewhat similar to the creep strain of concrete under sustained loading. For higher maximum stress levels, SFRC shows greater resistance to deformation per cycle and the resistance increase with the increase of steel fiber content.

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